REQ. NO. 8-9133

Reclamation Review

The International Journal of Land Reclamation

ELLIOT LAKE LABORATORY
CANMET, E.M.R.
APR 14 1981
RECEIVED
ELLIOT LAKE, ONTARIO

CONTRACT REPORT NO. 0SQ79-00033

Volume 3 Number 3

1980

10 pp

Reclamation Review, Vol. 3, pp. 169-177 (1980)
Printed in the U.S.A. All rights reserved

0160-788X/80/030169-13$02.00/0

Effect of Surface Treatment of Tailings on Effluent Quality

D. R. MURRAY

Agronomist, Elliot Lake Laboratory, Mining Research Laboratories, Canada Centre for Mineral and Energy Technology, Department of Energy, Mines and Resources Elliot Lake, Ontario

and

D. OKUHARA

Research and Development, Rio Algom Mines Ltd. Elliot Lake, Ontario

Successful reclamation treatment, in preparation for long range abandonment of mining wastes, involves both surface treatment and water quality control containment of waste solids and liquid contaminants. This paper describes use of lysimeters containing 125 tonnes of tailings to determine the impact of gravel, sawdust and vegetation as surface treatments on the quality and quantity of effluent produced from sulphide containing uranium mill tailings. Over a five-year period these treatments were observed and compared with bare tailings where no surface addition was made. The treatments did not alter the effluent quality to a level acceptable to regulatory requirements. Surface treatments did not appear to affect the leaching of Ra-226, NH_4 and NO_3. The concentration of Fe, SO_4, Cu, Pb, Al increased with the rise of acidity as the pH changed from pH 9.5 to pH 2 in four and one-half years. However the rate and extent of changes of some of these parameters vary with the treatment. The experimental results for the observed trends are presented with limited explanation. Original design problems and unexpected delays in tailing reactions have made firm conclusions impossible at this stage. This data, however, provides a base for further investigation and development of explanations and firm conclusions, as to the role of surface treatment in long-term waste abandonment.

INTRODUCTION

EFFLUENT WATER from surface deposited uranium tailings that contain sulphide minerals has been recognized since early 1970 as a major source of water pollution. The installation of water treatment facilities at the effluent discharge points have alleviated some of the problems, but do not stop the generation of contaminants and require constant surveillance.

Copyright, Minister of Supply and Services, Canada.

Studies have been made to reduce wind and water erosion of the surface and to improve the aesthetic quality of waste areas (Murray and Moffett, 1977; Murray, 1973; Dunn, 1971). Several alternative surface treatments have been developed over the past ten years (Melis and Dunn, 1972; Melis and Augsten, 1972; Dunn, 1974). These treatments have reduced erosion and have improved the appearance of the area, but their impact on effluent water quality and quantity has not been known.

Laboratory studies were found to be insufficient in providing adequate rooting depth and realistic profiles of texture, reactivity and mois-

ture distribution (Melis and Augsten, 1972; Murray, 1972; Silver and Ritcey, 1980). Field sites of old tailing ponds were too large to permit practical evaluation and experimental control. It was believed that tailings would oxidize quickly and surface treatments could then be applied and their impact monitored. Only major impacts would be considered significant to a mining reclamation or waste management program. The experiment described in this report was on the quality and quantity of effluent generated from a primarily non-saturated zone of tailings, 1.5 m deep, on which various surface treatments had been carried out. As it occurred, the tailings did not rapidly oxidize and consequently the surface treatments were applied to relatively fresh mill tailings. The treatments used were gravel, sawdust, (locally available material, to control surface erosion) and vegetation. The sawdust was felt to have potential for stopping oxygen penetration into the tailings. Vegetation was currently the most economical and attractive treatment. Some workers believed that vegetation would restrict oxygen penetration and evapotranspire water thus reducing effluent quantities (Silver and Ritcey, 1980; Vogel, 1975). Bare tailings which were known to produce unacceptable effluent were used for comparison. A water balance was attempted, but the major effects reported here have been on water quality impacts over time.

EXPERIMENTAL DESIGN

Pit Construction

Four pits 9 m × 9 m by 1.5 m deep with sides sloped at 45 degrees were excavated in a well drained, gently sloping glacial deposit. At least 15 cm of sand cushion was placed as backing for a 30 mil Hypalon liner which extended approximately 30 cm above and around the pit edge to isolate the pit from the natural ground surface. A 5.8 m length of 10 cm in diameter (ϕ) corrugated polyethylene drainage tile with a fabrene covering was placed at the bottom of each pit. One end was blocked with a Hypalon cover and the other end was connected to a 5 cm ϕ polyethylene flexible pipe. A gravel filter (2 cm or less in size) was placed over the entire length of the drainage tile to a depth of 8 cm. The flexible pipe connected to the tile passed through the Hypalon liner and followed a 1% or greater grade down the slope to the sampling shed. An additional 5 cm ϕ polyethylene overflow pipe passed through the liner at the ground level and followed a 1% or greater grade to the sampling shed. The pit construction detail is shown in Figure 1 and the layout of the four pits and sample shed is shown in Figure 2. The installation of the liner and all connections and seams were supervised by the manufacturer's staff to ensure the integrity of the pit liner and water collection system.

Tailings Addition

From September 9th through October 10th, 1975, fresh lime-neutralized regular mill tailings were pumped into each pit, allowed to settle, and then the excess supernatant solution and drainage tile effluent was pumped back to the mill for disposal. The tailings were added in sequence to the pits to ensure that they were as uniform and nearly identical as practically possible.

A 5 cm ϕ polyethylene line from the regular mill tailings line was used to supply the calculated 90,900 L each pit required. The pulp density of the tailings supply was 17% solids and the tailings solution was delivered at 273 L/min over a 16 hour workday. The spreading of the tailings was achieved by two floats to support the end of the tailings line and a tether to direct the location of the end of the pipe which would permit deposition of tailings at any required position in each pit. As the pits were progressively filled, the cycle time for emptying decant water and filling with fresh tailings solution became shorter and shorter. Approximately 20 fillings were required for each pit and all were filled simultaneously before winter freeze-up occurred. Each completed pit contained approximately 125 tonnes of tailings.

Surface Treatment

From the completion of pit construction and tailing addition (October 1975) until August 1976 no treatment was done to the pits or tailings as they settled and drained freely. In August 1976, the surface of the tailings in each pit was rototilled and the surface treatments applied. Pit 1 was covered with 15 cm of gravel. Pit 2 was covered with 15 cm of sawdust. Pit 3 received no treatment and remained as bare tailings. Pit 4 was vegetated. It received a limestone application of 22.4 tonne/ha, fertilizer 5-20-20 at 112 kg/ha, and 0-46-0 at 112 kg/ha in preparation for seeding with 17 kg/ha Red Top and 17 kg/ha Creeping Red Fescue. Subsequent fertilization was done to Pit 4 on a monthly basis during the growing season during the 4 subsequent years of the study at a rate of 224 kg/ha of 10-20-20 fertilizer. This was following a reclamation procedure already

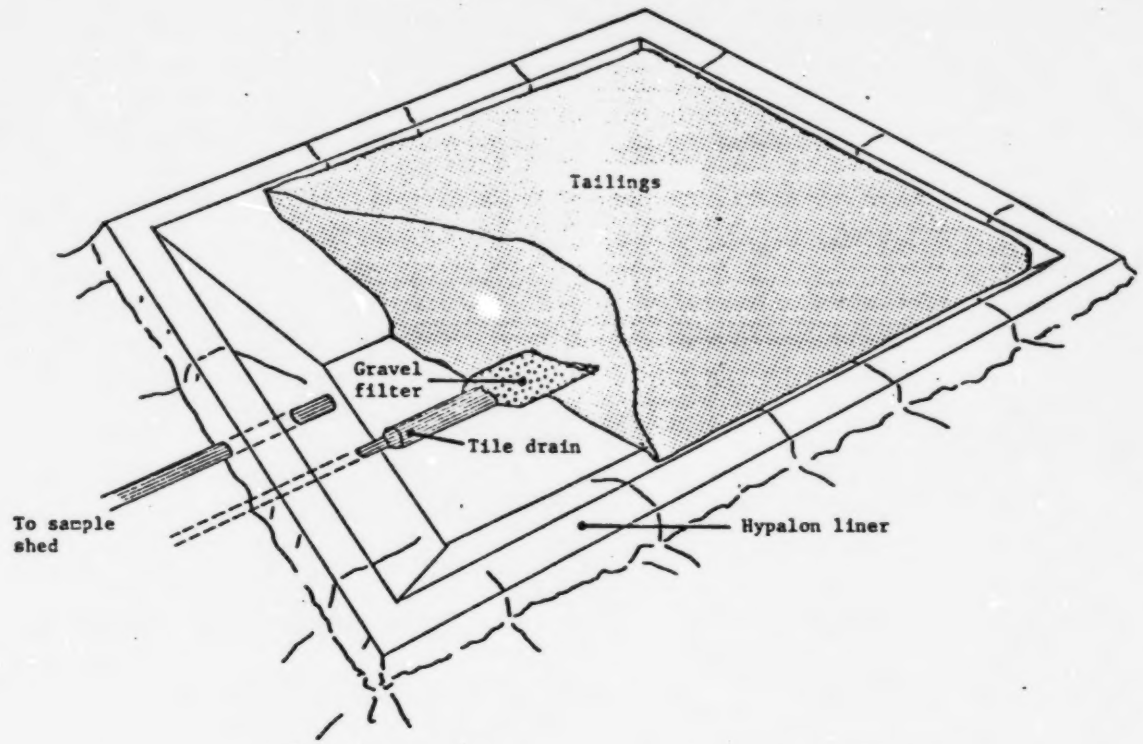

Figure 1. Pit construction detail (Okuhara, 1976).

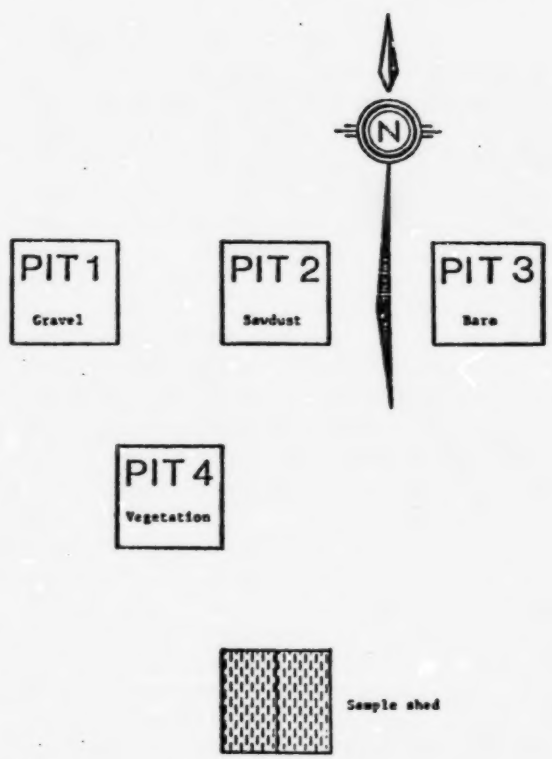

Figure 2. Pit layout and sample shed.

developed for the tailings (Murray and Moffet, 1977). The other three pits and their treatments were not altered during the test period. No irrigation or protective covering from natural precipitation was applied. No cutting or removal of vegetation occurred.

Sampling and Analysis

All the surface and tile drainage lines were directed to a common 6 m × 7.3 m sample shed at the base of the slope. All drainage to the shed was by gravity with no restriction on water flow and no watertable was intentionally maintained. Each drainage tile line went directly to a 227 L polyethylene tank. To measure the total volume of solution discharging from each pit, a calibrated level control sump pump was placed in the tanks which removed known quantities of solution from each tank. Electrical counters registered the number of times the sump pump operated.

A rain gauge was maintained within 30 m of the pits and sample shed during the frost free period of each year. Regional annual climatological data was also obtained from regional weather station records.

Table 1. Analytical Techniques

List of Techniques used in Analysis of Samples		
Solution		
Alkalinity	Titration	To pH = 4.2
Acidity	Titration	To pH = 8.3
Total Dissolved Solids	Gravimetric	
NH_4	Selective electrode	
NO_3	Colorometric	U violet (220 mμ)
Pb, Al, Fe, Cu	Atomic Adsorption	
Th, U_3O_8	x-ray analysis	
SO_4	Titration	Benidine dihydrochloride reaction followed with acid titration.
Ra-226 (dissolved)	De-emanation Method	
Solid		
Ca	Atomic adsorption	
CO_3	Leco Combustion	
U_3O_8, Th	x-ray analysis	
Total S	Leco Combustion	
Insoluble sulphide	Gravimetric	HCl digestion followed by nitric acid-potassium chlorate digestion.
Ra-226	De-emanation Method	

Records of rainfall and effluent flow were maintained on a daily basis on working days and the accumulative values for holidays and weekends. Measuring of flow quantities was from spring thaw in March or April until freeze-up in November or December. Servicing of the pumps was done during December to March with standby equipment available during the frost-free season. Such data on flow quantities covers from March 1976 to December 1979. The tile drain effluent covers the 4-year period, but records for the overflow data and snow loads are irregular and subject to large error from short, fast flows and mid-winter thaws or rains.

Samples for analytical work were obtained directly from the effluent 5 cm ϕ line as they entered the collection tanks and were taken every two weeks starting at the first spring flow and continuing until the flow stopped the following fall or winter. Analyses varied with sample time, but all items in Table 1 were completed at least once a month when flows permitted samples to be obtained. Samples of the solid tailings were taken in October 1975, when the pit construction was completed. Five samples were taken from the top 25 cm of each pit.

Chemical analyses were done by standard methods (Welcher, 1963) except for nitrate which was done by measuring the solution absorbance at 220 mμ and ammonia which was analyzed with a specific ion electrode. Uranium and thorium were done by X-ray emission spectrometry using a Mo target at 50 kV and 36 mA excitation. The uranium L_α line was counted at 37.23° on a LiF (220) crystal using an 80 second count time. Background corrections were made using two positions bracketing the peak. Radium-226 was determined by a standard de-emanation method (Rushing et al., 1964).

Solid samples were treated with hydrofluoric acid to remove silica and the residue was dissolved in hydrochloric acid to give a solution for analysis.

RESULTS AND DISCUSSION

Solid analyses of surface samples of the material placed in the pits are reported in Tables 2 and 3. The fluctuation of these data shows the heterogeneity of the tailings, but also the similarity of the tailings from one pit to another.

Table 2. Tailings Surface Treatment Project—Solid Analysis Report (Okuhara, 1976)
(Samples Taken 6" Below Surface)

Sample Location	% Passing 200 mesh	% Ca	% CO_3	% Total S	% S as insoluble Sulphide	lb U_3O_8/T	lb Th/T	Ra-226 pCi/g
Gravel								
Centre	80.92	3.38	1.08	5.26	1.96	.26	1.49	435
N.W. corner	19.8	1.04	.63	3.41	2.25	.18	.48	199
N.E. corner	51.8	2.60	.73	5.00	2.09	.26	1.23	
S.E. corner	24.0	.87	.33	3.77	1.99	.24	.52	
S.W. corner	32.77	1.62	.57	4.91	2.70	.26	.91	
Sawdust								
Centre	64.86	2.43	.88	5.01	2.27	.36	1.07	328
N.W. corner	7.19	.26	.29	2.25	1.41	.16	.21	189
N.E. corner	21.17	.97	.45	4.50	2.74	.24	.52	
S.E. corner	28.07	1.49	.54	3.06	1.28	.34	.73	
S.W. corner	45.65	2.40	.68	4.85	2.07	.36	1.17	
Bare								
Centre	63.10	2.79	.82	5.15	2.91	.31	1.26	378
N.W. corner	37.0	1.75	.53	4.09	1.84	.24	.90	
N.E. corner	22.16	1.04	.49	3.98	2.14	.20	.55	
S.E. corner	24.75	1.10	.64	3.20	1.03	.20	.54	
S.W. corner	2.24	.21	.29	3.39	2.17	.17	.25	128
Vegetation								
Centre	26.39	1.20	.38	3.04	1.61	.17	.62	218
N.W. corner	27.74	1.27	.41	11.65	7.17	.29	.71	
N.E. corner	28.96	1.01	.44	3.55	2.04	.18	.55	
S.E. corner	22.27	1.00	.57	4.55	3.03	.22	.53	
S.W. corner	5.08	.25	.33	12.03	11.81	.22	.28	178

Table 3. Tailings Surface Treatment Project—Solid analysis Report

Sample Location	% Mg	% Al	% Mn	% Cu	% Zn	% Co	% Ni	% Pb	% Fe
Gravel									
Centre	0.179	5.39	0.008	0.008	0.003	0.004	0.005	0.073	2.61
N.W. corner	0.060	3.41	0.003	0.003	0.001	0.002	0.004	0.037	2.33
N.E. corner	0.109	4.66	0.007	0.007	0.003	0.002	0.005	0.059	2.71
S.E. corner	0.059	3.30	0.003	0.003	0.001	0.004	0.004	0.042	2.29
S.W. corner	0.087	4.00	0.006	0.006	0.002	0.005	0.005	0.053	2.91
Sawdust									
Centre	0.101	4.27	0.007	0.007	0.003	0.005	0.004	0.067	2.68
N.W. corner	0.054	2.90	0.002	0.002	0.000	0.002	0.003	0.029	1.66
N.E. corner	0.078	3.08	0.004	0.004	0.001	0.004	0.004	0.042	2.71
S.E. corner	0.079	3.96	0.005	0.005	0.001	0.002	0.005	0.048	1.72
S.W. corner	0.106	4.44	0.007	0.007	0.003	0.004	0.006	0.064	2.48
Bare									
Centre	0.123	5.21	0.008	0.008	0.003	0.004	0.006	0.073	2.68
N.W. corner	0.085	4.07	0.006	0.006	0.003	0.003	0.005	0.054	2.26
N.E. corner	0.068	3.41	0.003	0.003	0.002	0.002	0.004	0.039	2.52
S.E. corner	0.064	3.34	0.002	0.002	0.001	0.002	0.004	0.041	2.00
S.W. corner	0.043	2.73	0.002	0.002	0.001	0.002	0.004	0.028	2.55
Vegetation									
Centre	0.069	3.30	0.004	0.004	0.002	0.002	0.005	0.039	1.88
N.W. corner	0.073	3.60	0.004	0.004	0.002	0.007	0.007	0.048	6.25
N.E. corner	0.063	3.08	0.003	0.003	0.001	0.003	0.006	0.039	2.24
S.E. corner	0.063	3.41	0.004	0.004	0.001	0.002	0.005	0.040	2.98
S.W. corner	0.044	2.86	0.003	0.003	0.001	0.008	0.007	0.039	6.78

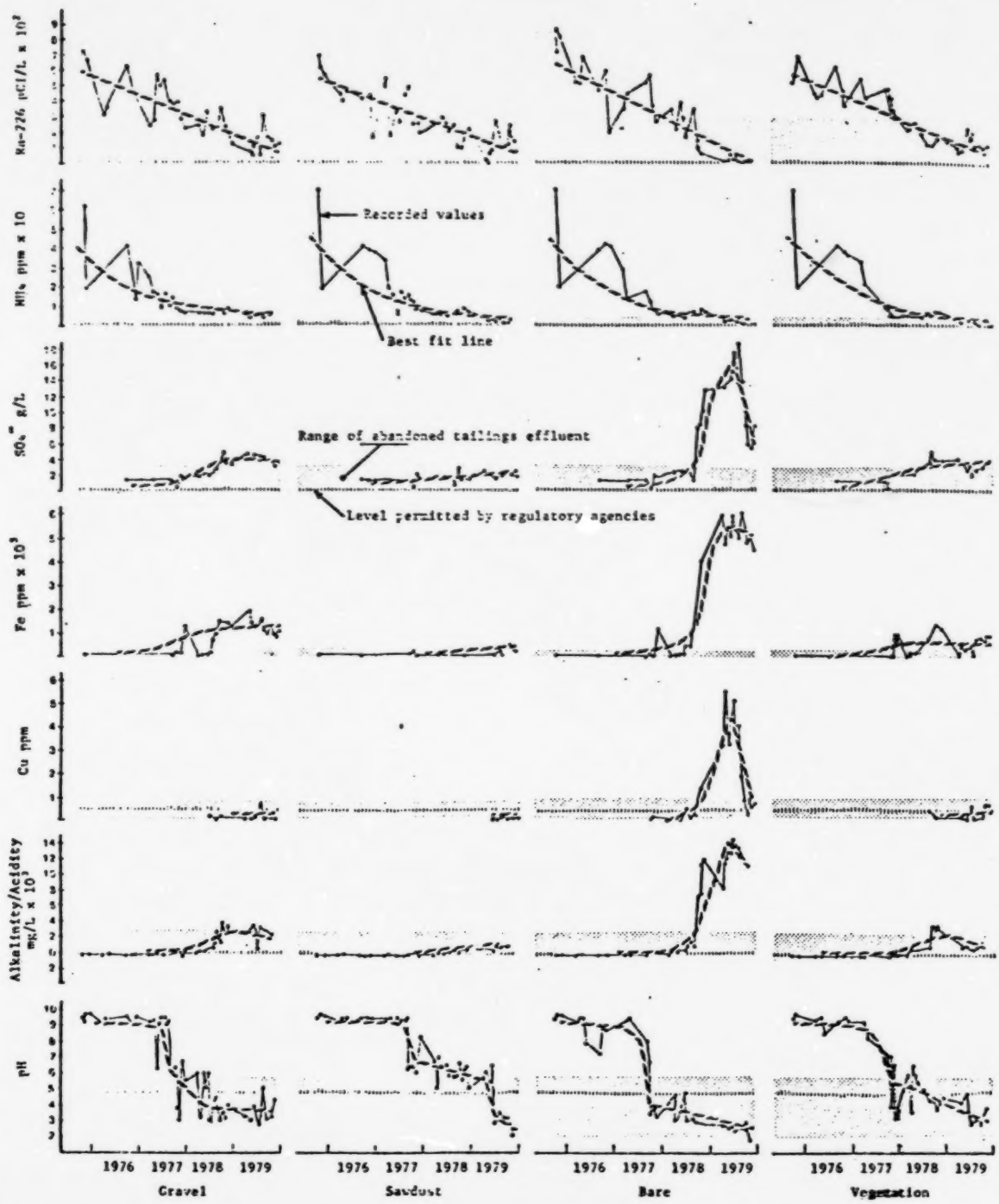

Figure 3. Effluent quality time series.

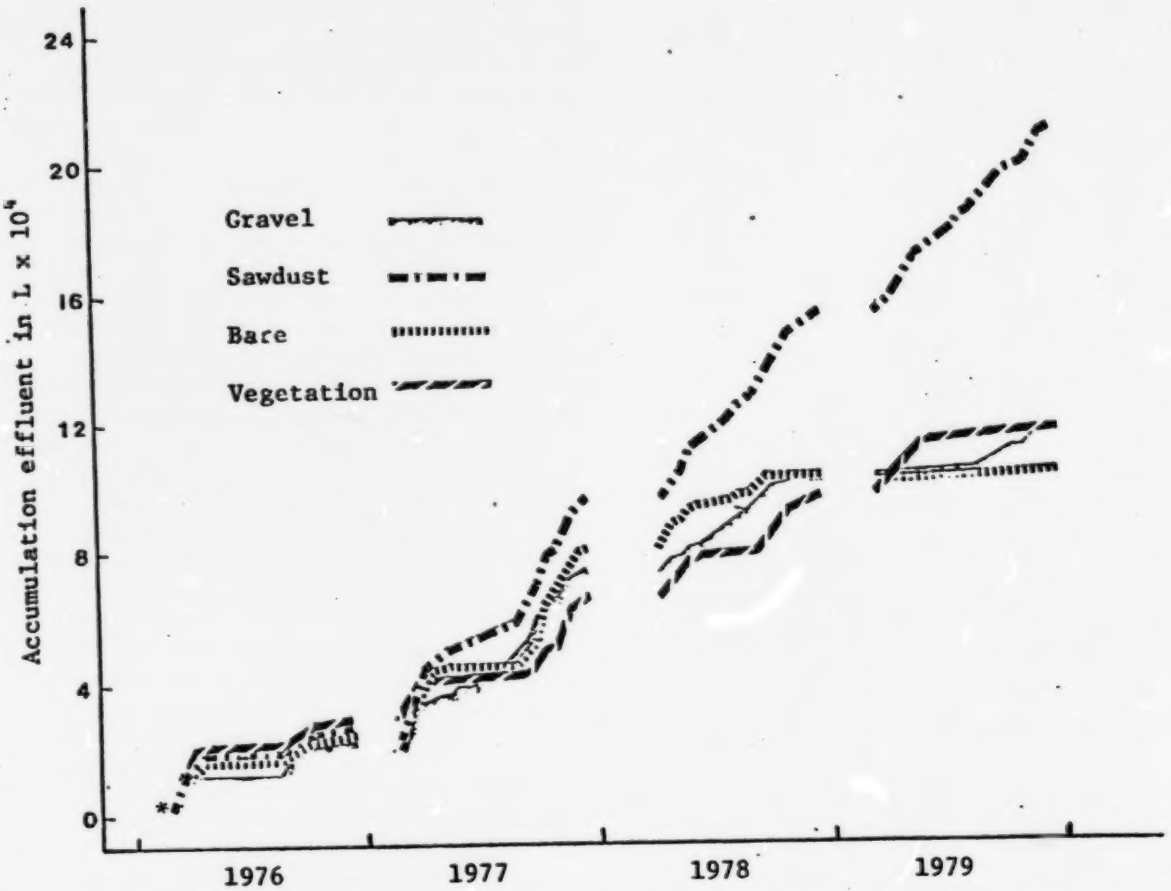

Figure 4. Effluent accumulation over four years.

A number of time-series graphs are shown in Fig. 3, depicting the quality of the effluent from the tile drainage from each pit. Individually recorded values are joined with a solid line while a dashed line indicates the best fit line for interpretive purposes. The shaded area of each graph is the range within which effluent from abandoned tailings in the Elliot Lake area have historically fallen (Ontario Water Resources Commission, 1970). The dotted horizontal line across each graph is the maximum desirable or permissible level of that assay by regulatory agencies (Dept. of the Environment; MacLaren Ltd., 1978). In the case of pH the line represents the minimum desired level.

Irrespective of the fluctuation of each parameter, all effluent is of unacceptable quality. In all cases the values are in, or appear to be approaching, the shaded areas representing the range found at abandoned tailings. It is expected that the test pits should reach an equilibrium at some stage.

No direct proof of the long-term impact of the surface treatments can be given and it is unlikely that full credit for pit responses can be attributed entirely to the surface treatment. Some trends can be seen, however, and these assist at understanding the problem of water quality improvement.

Radium-226, NH_4 and NO_3 (not shown) appear to be acting independently of treatment. It can be considered a straight leaching process. Similar results have been found by Bryant (1979) regarding Ra-226 leaching as effected by surface additives.

Heavy metals such as Cu and Pb (Cu only

shown on Fig. 3) follow the acidity pH levels and thus are only indirect problems resulting from the pyritic oxidation and subsequent lowering of the pH. The resulting acid pore water dissolved the heavy metals.

Sulphate, iron and acidity are all involved in the major tailings reaction of pyrite oxidation and subsequent pH change. As an example, the bare pit oxidation progresses slowly until a rapid drop to pH 2–3 occurs. The oxidation then progresses rapidly, but eventually appears to be decreasing even though the pH remains low. There are numerous possible chemical reaction pathways that could explain these results, yet there is insufficient knowledge to confirm any one process. Rather than entering into numerous speculations, it will suffice to say that the reactions are more complex than anticipated. More data is required.

Time lag is important in this study. In the first two years little change occurs until the pH drops from pH 9.5 to either pH 2–3 or pH 5–6. These changes occur rapidly and then stay constant for about one year. A response to this pH drop takes one year before the acidity, heavy metals and sulphate concentrations show the effect to any great extent. The real effect of the pH change may not be evident yet. The bare pit had a rapid pH drop, but the other pits responded slightly by dropping to a pH of 5–6, but have dropped to pH 2–3 over another two years. The surface treatments could be responsible for the suspected stabilizing influence, or just delaying a response similar to the bare pit.

The effluent accumulation over the 4-year experimental period is shown in Figure 4. Figure 5 shows the estimated loadings of various items for each pit over the four year period. The time lag is seen here also plus the extent of contamination possible as influenced by flow volume as well as mean concentration level. Although pit 2 (sawdust) is different from the others, in Figure 4 it is not sufficient improvement in effluent quality (Figure 5) to be of practical value to the industry.

Because of the many implications of the time lag it is difficult to know if the pits have reached their equilibrium or will respond in the same way as the bare pit at some later date.

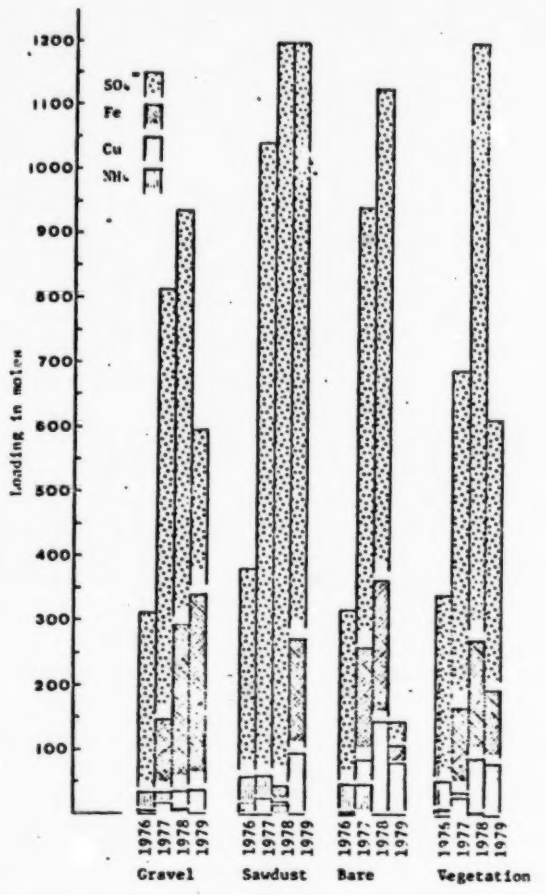

Figure 5. Estimated loadings for various constituents.

CONCLUSIONS AND RECOMMENDATIONS

The four test pits were set up as identically as possible (except for the surface treatments) and exposed to the environment for four years. As a result of observations it appears that the surface treatments have not prevented the deterioration of effluent water passing through the nonsaturated portion of uranium mill tailings.

There are differences between the responses of the individual pits which may be attributed to the surface treatment. The extent and value of such an impact at this stage and the implications to a field situation is speculative at best. The addition of gravel, sawdust, or vegetation as an improvement over bare tailings can be based only on surface stability, reduced erosion and improved aesthetics. They are not in themselves the full answer to water quality improvement or effluent quantity reduction or elimination. The observations, however, have demonstrated the complexity of the effluent contamination and its evaluation.

It is hoped that the results of this program will assist others considering the processes of effluent contamination and its response to treatment. The Lysimeter pits constructed for this

study are still being observed and preparation is now underway to make more detailed studies of the effluent and tailings profile. As a result of other work that CANMET has been involved with, this experiment will be a valuable component for the development of a hydrogeochemical model of uranium tailings of the Elliot Lake Camp.

REFERENCES

Bryant, D. N., D. B. Cohen and R. W. Burham. 1979. Leachability of radioactive constituents from uranium mine tailings, status report. Report EPS 4-WP-79-4.

Dean, K. C. and R. Havens. 1972. Stabilization of problem mineral wastes. U.S. Bureau of Mines. Salt Lake City Metallurgy Research Centre, Salt Lake City, Utah.

Dept. of the Environment. Existing metal mining liquid effluent guidelines. Fisheries Act, Dept. of the Environment.

Dunn, R. W. 1971. Vegetative stabilization of inactive tailings surfaces: Part I: Literature survey, preliminary objectives and winter research program for 1971. Rio Algom R71-15.

Dunn, R. W. 1974. Vegetative stabilization of inactive tailings surfaces: Part IV: Treatment for reducing and acid load in tailings seepage. Rio Algom R74-02.

James F. MacLaren Ltd. 1978. Environmental assessment of the proposed Elliot Lake uranium mines expansion, Vol. 4.

Melis, L. A. and R. A. Augsten. 1972. Vegetative stabilization of inactive tailings surfaces: Part III: Winter, summer and fall research program for 1972. Rio Algom R72-09.

Melis, L. A. and R. W. Dunn. 1972. Vegetative stabilization of inactive tailings surfaces: Part II: Summer and fall research program for 1971. Rio Algom R72-01.

Murray, D. R. 1972. Factors affecting revegetation of uranium mine tailings in the Elliot Lake area: Part II: Chemical conditions; Investigations Report IR 72 55. Mines Branch (since renamed Canada Centre for Mineral and Energy Technology [CANMET]), Department of Energy, Mines and Resources.

Murray, D. R. 1973. Vegetation of mine waste embankments in Canada. Information Circular IC 301, Mines Branch (since renamed Canada Centre for Mineral and Energy Technology [CANMET]), Department of Energy, Mines and Resources.

Murray, D. R. and D. Moffett. 1977. Vegetating the Elliot Lake uranium mine tailings. J. Soil and Water Conservation 32(4):171–174.

Okuhara, D. N. 1976. Effect of surface treatment of tailings areas on quantity and quality of seepage, Part I. Rio Algom Ltd., Mining Division Research and Development, R 76-01.

Ontario Water Resources Commission. 1970. A report on an industrial waste survey of Rio Algom Mines Ltd., Buckles, Lacnor, Nordic, Elliot Lake, Ontario. Division of Industrial Waste, OWRC.

Rushing, D. R., W. J. Garcia and D. A. Clark. 1964. The analysis of effluents and environmental samples from uranium mills and of biological samples for radium, polonium and uranium. pp 187–230, in Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vol. II. Int. Atomic Energy Agency, Vienna.

Silver, M. and G. M. Ritcey. 1980. A simulated study on the effects of bacteria, organics and salt solutions on uranium mine mill tailings from Elliot Lake, Ontario. Division Report MRP/MRL 80-82, CANMET, Energy, Mines and Resources Canada.

Vogel, W. G. 1975. Requirements and use of fertilizer, lime and mulch for vegetating acid mine spoils. Proc. 3rd Symp. on Surface Mining and Reclamation, Vol. II, Louisville, Kentucky.

Welcher, F. J. 1963. Standard Methods of Chemical Analysis, 6th edition. Van Nostrand, Princeton, N.J.

POOR

QUALITY

ORIGINAL